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Inelastic Scattering Effects in Grazing Incidence XPS
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Beamline: X24A

Introduction: Inelastic scattering makes up a large contribution to x-ray photoemission spectra. Because of the complexity of the scattering processes involved and the uncertainty of the relevant physical parameters, quantitative modeling of the inelastic contribution to a photoemission line is inaccurate. As a result, quantitative XPS is difficult to perform in many cases. Grazing incidence x-ray photoemission spectroscopy (GIXPS) reduces the inelastic background considerably by limiting the depth of interaction. We are interested in a quantitative measure of the inelastic scattering as a function of the angle of incidence. This can then be related to the interaction depth. Inelastic background measurements as a function of interaction depth are also a measure of the inelastic mean free path of photoelectrons in a material.

Methods and Materials: The method consists of taking spectra from a clean sample at a series of grazing angles with a low-divergence beam of monochromatic, low energy x-rays. X-rays at 1820 eV were produced on X-24A using an InSb(111)-KDP(200) crystal pair in the monochromator (ΔE=0.4 eV). The beam was incident at an angle of incidence $0 < \varphi < 1.5^\circ$ on a very flat Si (100) sample mounted on a goniometer in UHV. We were interested in inelastic spectra from Si, particularly the Si 2p lines that are used to study the characteristics of gate dielectric layers with GIXPS. In this case, the Si was cleaned by lightly sputtering at low energies. The photoemission spectra were acquired with a double-pass cylindrical mirror analyzer at a pass energy of 50 eV.

Results: The resulting spectra are shown in the figure below. In the immediate 10 eV below the Si 2p photoemission line ($2P_{3/2}$ and $2P_{1/2}$ lines unresolved here) the inelastic background is well duplicated over the entire range of incidence angles by a linear transition to a step which is 5% the height of the photoemission peak. The spectra thus show a marked reduction in the inelastic scattering which would normally be large for XPS with the source at conventional incidence angles.

Conclusions: The variation of 2p peak height from clean Si with incidence angle is accurately described by our model which includes the optical constants of the surface and the inelastic mean free path (IMFP) of the escaping photoelectrons. This indicates that the model is basically correct. Estimates for the reduced quantity of inelastic scattering allow for improved values for the subshell photoemission cross-sections for quantitative XPS, useful in the study of more complex Si surfaces deposited with multiple layers of gate dielectric materials.

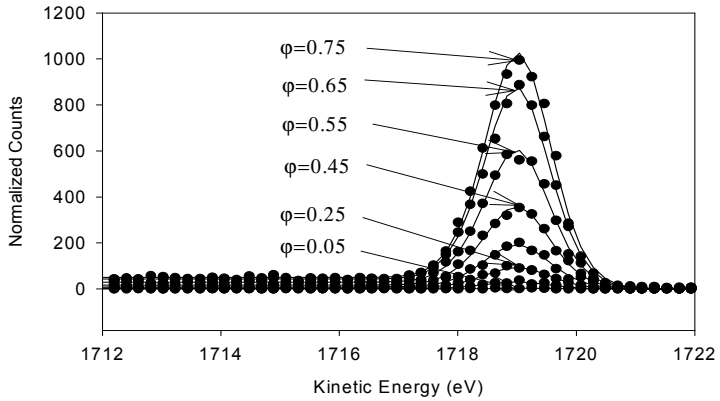

Fig. 1 Si 2p GIXPS spectra for $0 < \varphi < 0.75^\circ$ showing reduced inelastic background